Degradation of the EVE MEGS-A filters: Do we understand what is happening?

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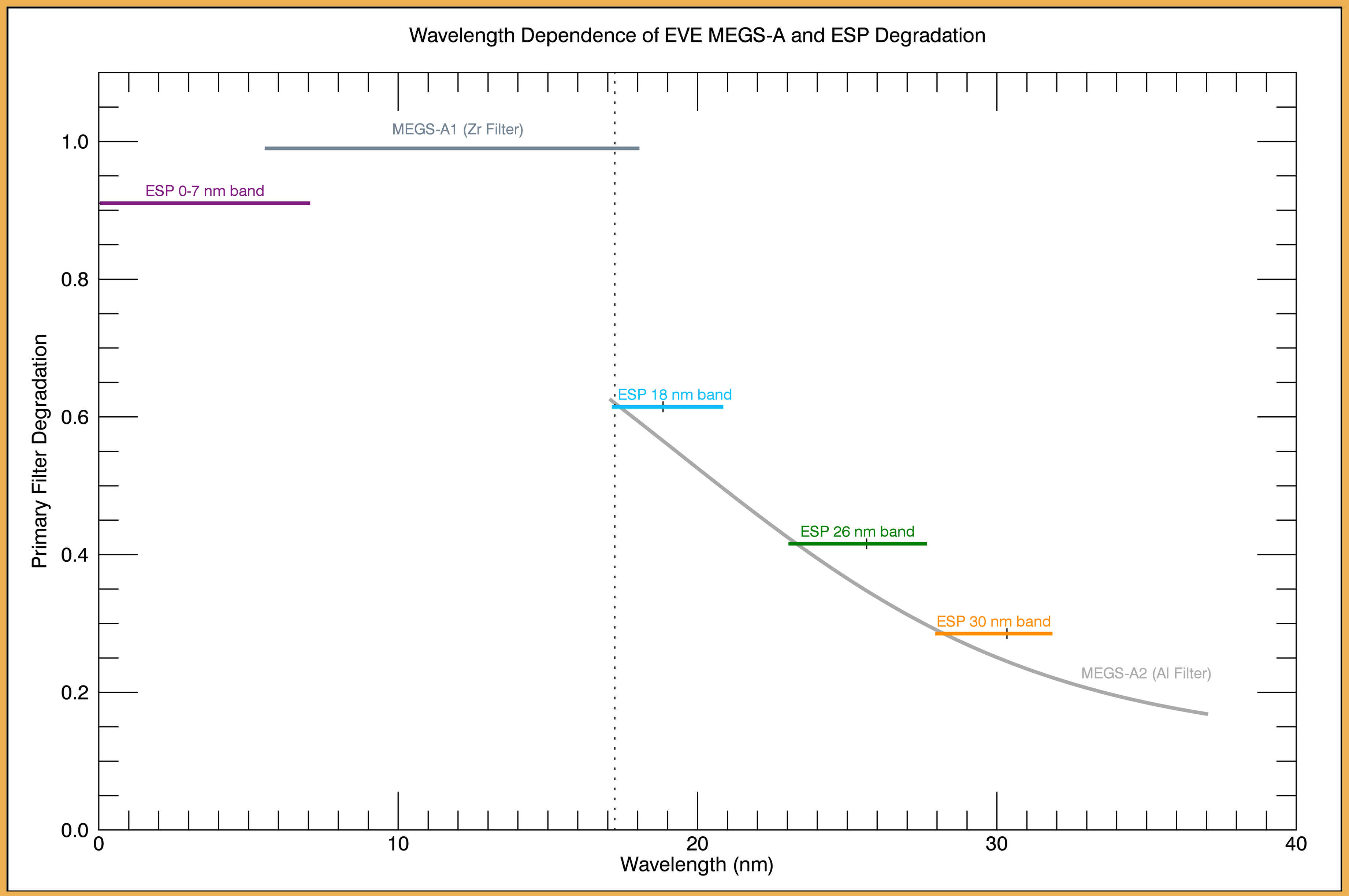
Introduction

The MEGS-A instrument on SDO/EVE is a grazing incidence spectrograph covering the wavelength range 6–36 nm with two slits[1]. The two slits are less than 1 cm apart and illuminate the same grating and detector. The difference between the channels is that one slit has a Zirconium filter (MEGS-A1) limiting the wavelength range to ∼6–18 nm, while the other slit (MEGS-A2) has an Aluminum filter transmitting >17 nm. The EVE/ESP instrument[2] also has an Al filter and shows similar degradation to MEGS-A2. The figure shows the degradation seen on EVE after 4 years on orbit. It is obvious that the Al filters have significant degradation, while the Zr shows no measurable degradation (these measurements are made by occasionally observing through a secondary filter that has very low exposure to the Sun and are checked by sounding rocket underflight calibrations).

EVE Degradation



Measured degradation of the EVE short wavelength channels (MEGS-A and ESP) after 4 years on-orbit. MEGS-A2 and all ESP channels have an Al filter as the first optical element, while the MEGS-A1 channel uses a Zr filter.

EVE

- MEGS-A2 and ESP use Al filters and show similar degradation
- MEGS-A1 has a Zr filter and shows no degradation
- All EVE channels are close together so should experience a similar environment

LYRA

- LYRA[3] is a 4-channel solar photometer on ESA's PROBA2 satellite[4]
- LYRA has Al- and Zr- filtered broad-band EUV photometers
- Both Al *and* Zr channels show significant degradation on LYRA[5]
  - This implies that Zr filters are not immune to degradation

Filter Construction and Orientation

EVE Filters:

☼ ⇒ C/Zr/C → MEGS-A1
☼ ⇒ Al/Ge/C → MEGS-A2
☼ ⇒ Al → ESP

LYRA Filters:

☼ ⇒ Zr → LYRA Zr Channel
☼ ⇒ Al → LYRA Al Channel

Carbonization

Traditionally we have thought that the degradation of solar EUV instruments has been due to outgassing hydrocarbons depositing on the optical surfaces and then polymerizing (see for example[6] for the modeling approach used). However, there is no apparent reason why the Zr filter on EVE should be resistant to carbonization while the Al filter (and Zr filter on LYRA) both degrade. If C was the degradation mechanism here, once a few atomic layers of C have formed on the surface *all* the filters would have similar surface chemistry.

Oxidation

The common wisdom is that metal films form a self-termination oxide layer and then remain stable. Indeed ground-based measurements of Al and Zr filters bear this out, and the theory for oxide formation (and termination) has been in place for many years[7]. However, as early as 1947 it was noted that enhanced oxide layers could grow under UV illumination[8]. We propose that the degradation seen on EVE and LYRA (and possibly other instruments) is predominately UV-enhanced oxidation of the front surface of the metal filters.

Conclusions

Yes — we think that we now understand the degradation seen on EVE MEGS-A and ESP (and LYRA). UV-enhanced oxidation of the metal-foil filters explains the wavelength dependence of the degradation, and also explains why the MEGS-A1 Zr filter does not show degradation. Water is one of the main outgassing species of a spacecraft[9], and provides a long lasting source of Oxygen. The carbon layer protects "caps" the Zr from oxidation in MEGS-A1. We can further say that because the ESP does not degrade twice as fast as MEGS-A2, that the oxidation is occurring primarily on the front surface. ARJ has submitted a NASA H-TIDeS-LNAPP proposal to study the oxidation of metal-foil filters in the laboratory to confirm these results.

Suggestions

If you are currently designing a solar-viewing instrument with a metal optical surface facing the Sun we would strongly recommend that the surface be protected from oxidation with a capping layer. This is a common practice in the EUV lithography community to protect surfaces from degradation. Even though we believe that in modern instruments oxidation, rather than carbonization is the primary cause on on-orbit degradation of filters, this does not mean that we should relax the strict hydrocarbon cleanliness procedures we have been using.

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